

## OPERATORY WATER DISINFECTION SYSTEM

This application claims the benefit of U. S. Provisional Application No. 60/269,403, filed on 16 February 2001, which provisional

5 application is incorporated by reference herein.

### Technical Field

Ozone disinfection of operatory water lines, in particular dental operatory unit water lines.

### Background

There has been serious concern that microbial contamination of dental office water systems puts dental patients at risk of diseases. The problem of water contamination, especially when due to cross contamination from other patients, is greatest for patients with weak immune systems. Additionally, dental water can become contaminated from the water supply. More commonly, contamination results from growth of microbial biofilms on the inner surface of water lines. Such biofilms can include germs introduced from patients. Germs can slough off from biofilms as water passes through water lines. Thus, it is not uncommon for water coming out of dental hand pieces to have more than one million bacteria per milliliter while the water entering the dental lines has less than 100 bacteria per milliliter.

Existing systems do not remove microbial biofilms, do not provide failure warning are inconvenient, are expensive, require excessive dental labor and depend on perfect user compliance with manufacturers' instructions.

## Summary of the Invention

Our invention makes possible a small, low-cost and user-friendly ozone appliance for the professional dental office and other medical applications. It is based in part on the advantages gained in using dissolved ozone as a disinfectant. Ozone dissolved in water can not only disinfect water and water lines, it can also reduce gum bleeding, gingivitis, bad breath, teeth stains and oral bacteria. Additionally, it can aid in wound disinfection in surgery. Our invention introduces dissolved ozone into dental and surgical operatory water lines. This dissolved ozone attacks microbial contamination of water from dental and surgical operatory water lines and attached hand pieces and dispensing devices. Our system automatically kills waterborne germs and destroys biofilms where germs can hide and grow. It can, therefore, be used to disinfect water lines in dental operations and for other medical applications such as providing liquid containing ozone for cleaning and disinfecting skin prior to surgery (and tissue exposed during surgery). We believe it will also be readily applicable in the context of ophthalmic surgery. Further, a unit connected to operatory water lines can give an audible or other alarm if the water becomes unsafe.

Thus, the advantages of our ozone system are numerous. Ozone disinfection via our system is automatic, making it much more convenient for dental personnel. With our system, ozone disinfection automatically adjusts for variable water flow and quality. Further, ozone containing gas is separated from the water before the water is circulated with excess ozone converted to oxygen before venting. Moreover, ozone disinfection using our system does not depend on

strict user compliance as our ozone system provides failure warning. In addition, ozone is the only disinfectant that can inactivate all pathogens in a short time. Ozone can destroy endotoxins produced by bacteria and destroy biofilms. (Microorganisms do not develop resistance to ozone). Finally, ozone is user friendly. It does not cause allergic reactions, has no offensive taste, and will not cause problems if accidentally ingested (unlike other disinfectants). It also stops gum bleeding and disinfects wound sites.

## 10 Drawings

FIGS. 1-5 are schematic diagrams of different embodiments of the inventive operatory water disinfection systems having many components in common.

FIG. 1 schematically illustrates a first embodiment of our invention.

FIG. 2 schematically illustrates a second embodiment of our invention. The system of FIG. 2 differs from the system of FIG. 1 primarily in the way the ozone-containing gas is contacted and mixed with the water.

FIG. 3 schematically illustrates a third embodiment of our invention. The system of FIG. 3 differs from the system of FIG. 1 primarily by economizing the mixing and delivery processes with fewer components.

FIG. 4 schematically illustrates a fourth embodiment of our invention. The system of FIG. 4 differs from the system of FIG. 1 primarily by economizing the mixing and delivery processes with fewer components.

FIGS. 5 schematically illustrates a fifth embodiment of our invention. The system of FIG. 5 differs from the system of FIG.

1 primarily by economizing the mixing and delivery processes with  
fewer components.

FIG. 6 provides a schematic diagram of a preferred external  
circulation passageway enhancing the operation and effectiveness of  
the inventive operatory disinfection system.

### Detailed Description

The preferred embodiments of the drawings have comparable  
advantages in features such as convenience, reliability, safety, cost  
and size. Different embodiments, using different combinations of such  
features, may be preferred for different users with different  
requirements. In addition, some of the different features that are  
illustrated in the drawings can be interchanged among the various  
embodiments, and the drawings are arranged to illustrate the different  
features that can be combined and not to delimit one combination of  
features from another.

Our description will assume that the apparatus is installed in a  
dental operatory. The invention will first be explained relative to the  
embodiment illustrated in FIG. 1 and the detail illustrated in FIG. 6. The  
order of presentation will follow the flow passageways of the ozone-  
containing gas, the liquid and ozone-containing gas mixing system and  
the ozonated liquid delivery system. This will reveal aspects of the  
invention in an order that is understandable but differs from the order  
of importance of the features involved.

First, the device generates an ozone containing gas using corona  
discharge, preferably using the corona discharge generator 11  
disclosed in Burris' US patent 5,529,760. The corona discharge method  
is preferred over the ultraviolet (UV) method, because it can produce  
the much higher gas ozone concentration needed to achieve an ozone  
concentration in the liquid adequate for disinfection. The device  
dissolves the ozone in the liquid by mixing continuously during  
operation. (See mixing methods disclosed in Burris' US patents  
4,555,335; 5,207,993 and 5,213,773.) Our preferred mixing method

uses a positive pressure pump **12** (such as a piston, rotary vane, diaphragm, or, preferably, a gear pump) in a liquid bypass. In the bypass mixing method, a liquid line **13** from the treatment chamber **14** and the line **9** from the ozone generator **11** come together at the pump **12** inlet. The mixing pump **12** mixes the ozone-containing gas and liquid and pumps both through the bypass line **15**, which preferably includes a static mixer **16** back to the treatment chamber **14**.

The air used to generate ozone is preferably first dried to a low dewpoint to improve the efficiency of ozone generation. This may be accomplished by use of replaceable desiccant cartridges **42** or an air drying system. Replaceable desiccant cartridges **42** can be protected from loss of drying capacity by entry of moist air when the system is not operating through the use of spring-loaded check valves **43** at the entrance and exit passageways to the cartridge. It would be advantageous to make use of the operatory supply of dry air **41** through regulator **40** to provide reduced dew point air for use in generating ozone in the device. This would also extend the life of the desiccant. More expensive sources for generator supply gas are oxygen generators or replaceable oxygen tanks. The use of oxygen instead of air greatly increases the ozone generator **11** efficiency and ozone output.

With a constant flow of ozone containing gas in excess of what can be dissolved according to Henry's law, the ozone concentration in the liquid is maintained at the desired level during the operation of the device. One of the great advantages of ozone is that according to Henry's law, the dissolved ozone concentration is determined by the partial pressure of ozone in the gas rather than the amount of ozone so long as there is an excess of ozone.

The ozone containing gas is separated from the liquid after mixing, preferably by gravity in the treatment chamber **14**. The alternative methods of using a porous hydrophobic material **54** or a float valve **51** will be discussed in more detail relative to FIG. 5. The separated gas is passed through an ozone reducing material **20** before the gas is released to the atmosphere. Thus, no ozone gas is released from the device to the atmosphere, and bubbles are eliminated from

- the liquid output line where they might cause problems. The gas/liquid separation is preferably conducted at minimal pressure to reduce the solubility of the gas and the tendency of bubble formation after the liquid is outputted to atmospheric pressure. Liquid is prevented from
- 5 entering the ozone generator **11** preferably by use of a porous hydrophobic material **18** or a check valve **19**. Liquid is preferably prevented from entering the ozone reducing material **20** by use of a porous hydrophobic material **18** or **50**. The use of porous hydrophobic materials, such as polytetrafluoroethylene, eliminates moving parts
- 10 and thus improves reliability.

- The liquid supply can be either a pressurized water line **21** or a reservoir **22**, which can be refilled or changed when the liquid supply runs low. The liquid from a pressurized water line **21** should be connected according to locally accepted practices through back flow
- 15 preventers **23** and pressure regulators **24** as required, all of which are well known in the industry. The liquid from a pressurized water line **21** can be admitted to the operatory disinfecting system by a valve **25**, responsive to a float or liquid level sensor **26**, as needed to replace outputted liquid. Admission of replacement liquid from a reservoir **22**
- 20 can be controlled by a valve **25** as with a pressurized water line **21** or in the case where gravity will not be adequate, a pump **31** responsive to a float switch or liquid level sensor **26**.

- It is common for dental offices to have a master water valve that is shut off when there are no patients being treated in the office.
- 25 In the event of the contents of the reservoir **22** being consumed or the water system **21** turned off (by a master control valve in the facility) a pressure switch **32** or sensor can communicate with the control system **33** to signal a shortage of liquid supply and or shut down the operatory disinfection system. If the pressure switch **32** is
- 30 to be relied upon to shut down the operatory disinfecting system, we prefer that a bleeder valve or orifice **34** be installed in the supply line **21** upstream of valve **25**. This arrangement eliminates the possibility of the system remaining on after the water supply **21** is turned off. This situation can occur if no liquid is required by the operatory
- 35 disinfecting system to run down the pressure of the supply line **21**. Alternatively, a sensor, such as liquid level sensor **26**, can

communicate with a controller **33** to determine that the system has not put out any liquid for a predetermined period of time and can shut down the operatory disinfecting system, it is preferred that a warning is given prior to actually shutting the system down.

Second, the liquid containing dissolved ozone is outputted from the dissolving system at a controlled constant rate and pressure to points as close as possible to the outlets to atmospheric pressure. The pressure and flow rate in the circulating liquid line is regulated by appropriately sizing the liquid passageways and the circulating pump **30** (if used) or by use of devices such as pressure regulators **27**, pressure relief valves **28** and flow controllers **29**. The liquid not demanded by dental hand pieces **61**, syringes **62** and rinse cups **67** could be either recirculated to the mixing system at liquid return **38** or discarded as waste as shown in FIG. 6. A preferred and beneficial point of discharge as waste, via alternative line **71**, is the cuspidor **63**, this provides an air gap to the waste line **68** and allows ozonated liquid to flush and rinse the cuspidor **63**. With the flow of liquid containing dissolved ozone the objective is to prevent significant delays between ozonating and final use to avoid ozone concentration reduction caused by ozone reversion to oxygen. Ozone dissolved in water has a half-life of approximately 15 minutes before the ozone reverts to normal oxygen. Recirculating and reozonating the liquid has the advantage of requiring a smaller ozone generating and mixing system and providing more holding time to increase germ killing in the liquid. Discharging the ozonated liquid to waste has the advantage of possibly eliminating the circulation pump **30**. In either design, the concept is that when the device is turned on to make available ozonated liquid, the system operates continuously to produce more freshly ozonated liquid than the maximum that might be required. If desired, due to water quality considerations, a filter **37** can be added to the water inlet line and/or to the pressurized liquid circulating passageway.

The dental office disinfection system preferably should be installed in each operatory at the point where water is connected to the chair or treatment apparatus. Preferably, as detailed in FIG.6, the flexible tubing **65** connecting the treated water supply to the hand pieces **61** and syringes **62** should have an extra lumen **66** so that

ozonated water can be circulated continuously through the tubing. This would bring freshly ozonated water as close as possible to the point of use. In situations where the control valves are remotely located from the hand pieces **61**, it would be beneficial to have the liquid valve **64**

- 5 located at the hand piece **61**. One way to accomplish this is to make use of the commonly used foot operated control valve **69**, which controls the air supplied to the turbine of the hand piece **61**. In this arrangement, a relay valve **64** is actuated according to the air pressure received to determine the flow of liquid to the hand piece **61**.
- 10 For example, as more air pressure is applied (faster turbine speed, more heat is generated) more liquid is dispensed (for greater cooling).

Ideally, an ozone sensor **45** would be in the treated liquid passageway. The ozone sensor circuit would provide assurance that the system is operating properly or warn if it is not. For example, the sensor circuit could activate an alarm such as a beeper **46** and or a lamp **47** if the ozone concentration falls too low. In practice, this alarm could activate briefly each morning after the system was turned on, and then activate only if there were a problem with the system.

Another possibility is that after a time delay to get the system started, the sensor in communication with the controller **33** could prevent liquid outputting if the ozone concentration fell below an established minimum level. An alternate or additional ozone sensor **72** would be as close as possible to the point of use (possibly made as part of the hand piece **61** or syringe **62**) and further it could be powered by

25 battery or the sensor current to indicate to the user that ozone is present in the liquid or not. One possible way for the sensor **72** to communicate with the user is through a two-color light emitting diode where red indicates insufficient dissolved ozone and green indicates sufficient dissolved ozone. The ozone sensor could use an ORP

30 (Oxidation Reduction Potential) electrode, which is well known to those skilled in the art, or preferably, two dissimilar (with different positions in the electromotive series) metals in the liquid stream connected to generate a galvanic potential proportional to the ozone concentration. While use of an ozone sensor **45** to warn of system problems should be

35 adequate, additional sensor circuits to warn of low liquid pressure or flow rate could be added for additional safety.



The embodiment of FIG. 2 is substantially similar to the embodiment of FIG.1, but differs in the way ozone-containing gas is introduced and mixed with the liquid. Specifically the mixing pump **12** along with static mixer **16**, bypass passageway **15** and inlet passageway **13** has been replaced with an ozone-containing gas pump **55**, an ozone-containing gas passageway **56** and a gas diffuser **57**. The diffuser **57** is preferably the fine bubble diffuser disclosed in Burris' US patents 5,422,043 and 5,858,283. One advantage of this embodiment is possibly quieter operation. To further quiet and economize the operation, the ozone-containing gas pump **55** can be replaced with a solenoid valve **58** that makes use of the pressure supplied by the operatory air system **41**. The air treatment and ozone generator would then be configured for a pressurized application including a pressure relief valve **60** to prevent over pressurizing the gas system. The gas liquid separation, the control system and liquid delivery system remains the same as described with regard to FIG. 1.

The embodiment of FIG. 3 is similar to the embodiment of FIG.1, but differs in that the functions of the delivery and dissolving systems have been combined to be achieved with one pump. In this arrangement, the mixing pump **12** is configured to mix the ozone-containing gas and liquid, the gas and liquid mixture then preferably enters a static mixer **16** as in the preferred embodiment of FIG.1. At this point, the gas and liquid mixture are directed to an inline gravity liquid separator **39**. All of the gas and some of the liquid exit the upper region of the separator **39** and are directed to the treatment chamber **14**. Liquid exits the lower region of the liquid separator **39** and is directed to the exterior circulation passageway **6** as described in reference to FIG. 6. The pump **12** and the passageways are sized to provide the proper flow and backpressure to cause the treated liquid to flow through circulation passageway **6**. Alternatively, pressure controls **35** and liquid flow control **36** and gas flow control **8** can be used to direct the gas and liquid on the proper course at the proper pressure and at the proper flow rate.

The embodiment of FIG. 4 further economizes the embodiment of FIG.3. In this configuration the treatment chamber **14** is eliminated and the apparatus for contacting the ozone-containing gas with the liquid is

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similar the difference is in the separation of the gas from the liquid.

The gas/liquid separator **48**, using a float valve or preferably a porous hydrophobic material, separates the gas from the liquid and directs the gas to a passageway leading to an ozone reducing material **20** prior to releasing the gas to the atmosphere. The float valve type of gas/liquid separator **51**, as shown in FIG. 5, makes use of a float **52** riding on the liquid in a chamber allowing gas to pass through a valve port **53**, when the liquid level drops and blocks the exit of liquid through the valve port **53** when the liquid level rises. A porous hydrophobic gas/liquid separator **54**, as shown in FIG. 5, contains no moving parts; instead, it makes use of a porous hydrophobic material **50** resisting the flow of liquid through its porosity due to the low surface energy of the hydrophobic material **50**. The liquid only, exiting the gas/liquid separator **48** is directed to an external circulation passageway **6** and is preferably returned to the operatory water disinfecting device through water return **38**. Once the circulated liquid is returned to the device, it preferably travels through an ozone sensor **45** and then on to a pressure relief valve **28**, which can maintain the backpressure as required for dispensing the ozonated liquid along its circulation passageway **6**. At this point, the liquid is joined with the incoming liquid **44** in a region **49** upstream of where the ozone-containing gas and liquid are joined and mixed. This provides for recirculation of the liquid and also results in a higher concentration of dissolved ozone. The supply liquid is provided through a demand regulator **59**, this arrangement will also provide a draw from reservoir **22** if so equipped. In this embodiment the flows of the gas and the liquid can be controlled by flow controllers **29**, pressure relief valves **28** and orifices **36** but we prefer to use spring loaded check valves **43** and passageways sized according to the requirements for controlling the desired flows.

The embodiment of FIG. 5 further economizes the embodiment of FIG. 4. The two primary differences being: one; the circulated liquid is discharged to waste **68** such as in the cuspidor **63** and two; the mixing pump **12** can be replaced with a venturi injector **70** to add and mix the ozone-containing gas with the liquid. Since the effectiveness of the venturi injector is dependant upon liquid flow, it is preferable to include a pressure sensor **32** to warn of low incoming liquid pressure. It is also

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possible to make use of the pressure in the oxygen-containing gas supply **41** to aid in mixing the ozone-containing gas with the liquid.

The embodiment of FIG. 6 illustrates in detail the preferred arrangement of the circulation passageway **6** of the inventive device.

- 5 The treated liquid may also be dispensed to fill the rinse cup **67** and to rinse the cuspidor **63** through valves **77** and **73** respectively. As previously disclosed it is most desirous to place the output valves **62**, **64**, **73** and **77** and circulate the treated liquid as close to the point of treated liquid discharge as possible. In the non-recirculated version, the
- 10 liquid can flow through an ozone sensor **45** prior to discharge through alternate passageway **71** as shown in FIG. 5. This way the treated liquid is checked for ozone content at the completion of its intended purpose. The alternate flow passageway **71** can be used when the circulation destination is to waste **68** through the cuspidor **63**.

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